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SPECIFICATION

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# VARIABLE DISPLACEMENT COMPRESSOR

## TECHNICAL FIELD

The present invention relates to a variable displacement compressor incorporated in, for example, a refrigeration circuit of a vehicle air conditioner.

## BACKGROUND ART

A typical variable displacement compressor is disclosed in, for example, Japanese Laid-Open Patent Publication No. 2001-304102.

That is, a piston is contained in each of a plurality of cylinder bores defined in a housing. A rotor is provided to a drive shaft that is rotatably supported by the housing. The rotor rotates integrally with the drive shaft. A cam plate (swash plate) is supported slidably and tiltably by the drive shaft. A hinge mechanism is provided between the rotor and the cam plate. The rotary motion of the drive shaft is converted into the reciprocating motion of the pistons through the rotor, the hinge mechanism, and the cam plate. Accordingly, the compression of a refrigerant gas is performed. The hinge mechanism guides the cam plate so that the cam plate slides on the drive shaft while tilting. According to an inclination angle of the cam plate, the stroke of the pistons, that is, the displacement of the variable displacement compressor is changed.

The above-mentioned hinge mechanism comprises two arms extending toward the rotor from the cam plate, and a protruding portion that extends toward the cam plate from the

rotor and is inserted between facing wall surfaces of the two arms. This protruding portion has a couple of side faces, which face the facing wall surfaces of the arms, respectively. In a state where the protruding portion performs surface contact to, and is pressed on, one wall surface of the arms, power transfer between the rotor and the cam plate is performed. Hence, at the time of tilting of the cam plate, one of the arms is slid to the protruding portion while maintaining the state where a wall surface of one of the arms and one side face of the protruding portion perform surface contact.

In the above-mentioned hinge mechanism, it is desirable that the arms slide on the protruding portion in the state where the arms maitain surface contact to the protruding portion so as to attain smooth displacement change in the variable displacement compressor, i.e., smooth tilting of the cam plate. That is, if the cam plate is tilted by an offset action from an axial load resulting from a compression reaction force to make the protruding portion pry up from between the two arms, sliding friction between the arms and the protruding portion becomes large. Hence, there arise problems such as early abrasion of the arms and the protruding portion, that is, a durability drop in the hinge mechanism, and deterioration in displacement controllability of the variable displacement compressor caused by the hinge mechanism not operating smoothly.

It is necessary to make play of the protruding portion between both arms as small as possible within a range where smooth motion of the protruding portion to the arms is not impeded, so as to prevent the protruding portion from being pried from between the two arms. For that purpose, it is necessary to set a distance between the facing wall surfaces of the arms in the cam plate and a distance between the side

faces of the protruding portion in the rotor, respectively, with high accuracy. Hence, it is necessary to perform the finish-machining of the facing wall surfaces of the arms and the side faces of the protruding portion, respectively, with high accuracy. However, such highly accurate finish-machining becomes a factor which raises the manufacturing cost of the compressor.

## SUMMARY OF THE INVENTION

The present invention aims at providing a variable displacement compressor that achieves smooth displacement change while reducing machining costs.

In order to achieve the above-described object, the present invention provides a variable displacement compressor, in which a piston is accommodated in a cylinder bore in a housing, and a drive shaft is rotatably supported by the housing. A rotor is provided to the drive shaft such that the rotor rotates integrally with the drive shaft. A cam plate is supported slidably and tiltably by the drive shaft. A hinge mechanism is provided between the rotor and the cam plate. Rotation of the drive shaft is converted into reciprocation of the piston through the rotor, the hinge mechanism, and the cam plate. The cam plate is slid on the drive shaft by the guidance of the hinge mechanism to change the displacement of the compressor. The hinge mechanism includes a first hinge portion extending from a first member toward a second member. The first member is one of the rotor and the cam plate. The second member is the other one of the rotor and the cam plate. The second hinge portion extends from the second member toward the first member. One of the first hinge and the second hinge portions includes at least two wall portions, and the other is a protruding portion inserted between two wall portions. The wall portions have facing surfaces facing

each other. The protruding portion has a couple of facing surfaces each of which faces the facing surface of one of the wall portions. One of the facing surfaces of the protruding portion two-dimensionally abuts against one of the facing surfaces of the wall portions such that power is transferred between the rotor and the cam plate. A thin-walled portion is provided in at least one of the facing surfaces.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical cross-sectional view of a variable displacement compressor according to a first embodiment of the present invention;

FIG. 2 is a top plan view showing a rotor provided in the compressor in FIG. 1;

FIG. 3 is a top plan view showing a swash plate provided in the compressor in FIG. 1;

FIG. 4 is a partially enlarged cross-sectional view showing the engaging state of the rotor shown in FIG. 2, and the swash plate shown in FIG. 3;

FIG. 5 is a partially enlarged cross-sectional view showing a front end portion of a protruding portion of the swash plate in a second embodiment of the present invention;

FIG. 6 is a partially enlarged vertical cross-sectional view showing the variable displacement compressor provided with a ring member according to a third embodiment;

FIG. 7 is a partially enlarged cross-sectional view showing the contact state of the ring member and swash plate, shown in FIG. 6, in view of the top of FIG. 6;

FIG. 8 is a top plan view showing a rotor and a swash plate according to a fourth embodiment of the present invention; and

FIG. 9 is a side view of the rotor and swash plate shown in FIG. 8.

## BEST MODE FOR CARRYING OUT THE INVENTION

Hereafter, variable displacement compressors according to first to fourth embodiments of the present invention will be described. Each compressor is part of a refrigeration circuit of a vehicle air conditioner as will be explained. In addition, in the second to fourth embodiments, only the points different from those of the first embodiment will be explained. The same numerals will be assigned to the same or corresponding members, and their explanation will be omitted.

First, the first embodiment will be explained with reference to FIGS. 1 to 4.

(Variable Displacement Compressor)

FIG. 1 shows a vertical section of a variable displacement compressor (hereafter, simply a compressor). In FIG. 1, it is assumed that the left-hand side is the front of the compressor and the right-hand side is the back of the compressor.

As shown in FIG. 1, a housing of the compressor (compressor housing) comprises a cylinder block 11, a front housing member 12 fixed to the front end of the cylinder block 11, and a rear housing member 14 fixed to the rear edge of the cylinder block 11 through a valve and port assembly (valve assembly) 13.

Between the cylinder block 11 and front housing member 12, a crank chamber 15 is defined. A drive shaft 16 is rotatably supported through the crank chamber 15 by the cylinder block 11 and front housing member 12. An engine E that is a drive source of a vehicle is coupled to the drive

shaft 16 through a clutchless (constant power transfer type) power transmission mechanism PT. Hence, at the time of the operation of the engine E, the drive shaft 16 is constantly rotated in response to the supply of power from the engine E.

A substantially disk-shaped rotor 17 is fixed to the drive shaft 16 in the above-mentioned crank chamber 15 so that the rotor 17 rotates integrally with the drive shaft 16. A swash plate 18 as a cam plate having a substantially disk-like shape is contained in the crank chamber 15. Either the rotor 17 or the swash plate 18 is equivalent to the first member, and the other of the rotor 17 and swash plate 18 is equivalent to the second member. An insertion hole 20 extends through the center portion of the swash plate 18. The drive shaft 16 is inserted in the insertion hole 20, and the swash plate 18 is supported by the drive shaft 16 slidably and tiltably.

A hinge mechanism 19 is provided between the above-mentioned rotor 17 and swash plate 18. The hinge mechanism 19 permits the swash plate 18 to slide on the drive shaft 16 along with an axis L of the drive shaft 16 while synchronously revolving the swash plate 18 with the rotor 17 and drive shaft 16.

Cylinder bores 22 are formed in the above-mentioned cylinder block 11. The cylinder bores 22 are arranged at equal angular intervals around the axis L of the drive shaft 16. The cylinder bores 22 are extended along with the axis L of the drive shaft 16. A single-headed piston 23 is accommodated in each of the cylinder bores 22. Each piston 22 reciprocates in the corresponding cylinder bore 22. Front and back openings of each of the cylinder bores 22 are blocked by a front end face 13a of a valve and port assembly 13 and a corresponding one of the pistons 23, respectively, and a

compression chamber 24, the volume of which changes according to the reciprocating motion of the corresponding one of the pistons 23, is provided in that one of the cylinder bores 22. Each piston 23 is engaged to an outer circumferential portion of the swash plate 18 through a couple of shoes 25, which are hemispherical. Hence, the rotary motion of the swash plate 18 accompanying rotation of the drive shaft 16 is converted into linear reciprocation of each piston 23 through the shoes 25.

Between the valve and port assembly 13 and the rear housing member 14, a suction chamber 26 and a discharge chamber 27 are defined respectively. The valve and port assembly 13 has a suction port 28, a suction valve 29, a discharge port 30, and a discharge valve 31 respectively corresponding to each of the cylinder bores 22. Refrigerant gas from the suction chamber 26 is drawn into the compression chamber 24 through the suction port 28 and suction valve 29 in connection with each of the pistons 23 moving toward a bottom dead center position from a top dead center position. The refrigerant gas drawn into each compression chamber 24 is discharged into the discharge chamber 27 through the corresponding discharge port 30 and the corresponding discharge valve 31 after being compressed to a predetermined pressure in connection with the corresponding piston 23 moving toward the top dead center position from the bottom dead center position.

(Displacement Control Structure of Compressor)

As shown in FIG. 1, a bleed passage 32, a supply passage 33, and a control valve 34 are provided in the above-mentioned compressor housing. The bleed passage 32 connects the crank chamber 15 with the suction chamber 26. The supply passage 33 connects the discharge chamber 27 with the crank chamber 15. The above-mentioned control valve 34 consisting

of a solenoid valve is arranged in the supply passage 33.

Then, the balance of an introduction amount of a high pressure refrigerant gas to the crank chamber 15 through the supply passage 33 from the discharge chamber 27, and a derived amount of a gas into the suction chamber 26 through the bleed passage 32 from the crank chamber 15 is controlled by adjusting the opening of the above-mentioned control valve 34 by electric supply control to the control valve 34 from the outside. Accordingly, the internal pressure of the crank chamber 15 is determined. As a result of changing the difference between the internal pressure of the crank chamber 15, and the internal pressure of the compression chambers 24 according to the change of the internal pressure of the crank chamber 15 and changing the inclination angle of the swash plate 18 according to the internal pressure change of the crank chamber 15, the stroke of the pistons 23, i.e., the displacement of the compressor is adjusted. In addition, an inclination angle of the swash plate 18 is expressed by an angle to a plane orthogonal to the axis L of the drive shaft 16.

For example, when the opening of the above-mentioned control valve 34 decreases, the internal pressure of the crank chamber 15 decreases. Then, the inclination angle of the swash plate 18 increases, the stroke of the pistons 23 increases, and the displacement of the compressor increases. The maximum inclination angle of the swash plate 18 is regulated by a protrusion (maximum inclination angle regulating portion) 18a abutting against the rear face of the rotor 17, the protrusion 18a being provided in front of the swash plate 18.

On the contrary, when a valve opening of the above-mentioned control valve 34 increases, the internal pressure

of the crank chamber 15 rises. Then, the inclination angle of the swash plate 18 decreases, the stroke of the pistons 23 decreases, and the displacement of the compressor decreases. The minimum inclination angle of the swash plate 18 is defined by a minimum inclination angle defining portion 35 provided on the drive shaft 16.

The above-mentioned minimum inclination angle defining portion 35 comprises a coil spring 35a which is wound around the drive shaft 16, and a Circlip (snap ring) 35b which is fixed to the drive shaft 16 and functions as a spring seat for the coil spring 35a. The coil spring 35a urges the rear center portion of the swash plate 18 toward the front of the compressor, that is, in the direction where the inclination angle of the swash plate 18 increases.

In the above-mentioned drive shaft 16, the coil spring 36 is wound between the rear face of the rotor 17, and the front face of the swash plate 18. The coil spring 36 urges the front center portion of the swash plate 18 toward the rear of the compressor, that is, in the direction where the inclination angle of the swash plate 18 decreases. The urging force of the coil spring 36 and the urging force of the coil spring 35a of the minimum inclination angle defining portion 35 mentioned above, participate in the decision for the inclination angle of the swash plate 18.

(Hinge Mechanism)

As shown in FIG. 1, the swash plate 18 has a top dead center corresponding region TDC which locates the pistons 23 at the top dead center positions. The top dead center corresponding region TDC includes the central points of spherical surfaces of both of the shoes 25 corresponding to each of the pistons 23 at the top dead center position. As

shown in FIGS. 1 and 2, an engaging groove 41 is formed in a position, facing the top dead center corresponding region TDC of the swash plate 18, in the rear face of the above-mentioned rotor 17. The engaging groove 41 is formed by the two rotor-side protrusions 42 and 43 extending toward the swash plate 18 from the rear face of the rotor 17. Both rotor-side protrusions 42 and 43 are provided in advancing and trailing positions in the rotation direction (the direction shown by the arrow R of FIG. 2, or the reverse direction thereof) of the rotor 17.

The two rotor-side protrusions 42 and 43 function as two wall portions extending toward the swash plate 18 from the rotor 17 so as to form the above-mentioned engaging groove 41. The rotor-side protrusions 42 and 43 have side faces (facing surfaces) 42a and 43a which mutually face each other in the engaging groove 41.

As shown in FIGS. 1 and 3, in the front face of the above-mentioned swash plate 18, a protruding portion 44 extending toward the rotor 17 is provided in a portion facing the above-mentioned engaging groove 41. The protruding portion 44 includes two swash-plate-side protrusions 45 and 46. Both swash-plate-side protrusions 45 and 46 are located in symmetric positions in the advancing and trailing sides of the rotation direction over the top dead center corresponding region TDC in the rotation direction (the direction shown by the arrow R of FIG. 3, or the reverse direction thereof) of the drive shaft 16. In other words, the protruding portion 44 is made in the hollow structure where the two swash-plate-side protrusions 45 and 46 are left in both sides for weight saving in the swash plate 18.

In this embodiment, either the above-mentioned rotor-side protrusions 42 and 43 or the above-mentioned protruding

portion 44 is equivalent to the first hinge portion, and another of the above-mentioned rotor-side protrusions 42 and 43, and the above-mentioned protruding portion 44 is equivalent to the second hinge portion.

Both the above-mentioned swash-plate-side protrusions 45 and 46 are located in the engaging groove 41 from those end sides, respectively. Both the swash-plate-side protrusions 45 and 46 have side faces 45a and 46a which face away from each other. The side faces (facing surfaces) 45a and 45b can two-dimensionally abut against the side faces 42a and 43a of the rotor-side protrusions 42 and 43 respectively.

When the above-mentioned drive shaft 16 rotates in the direction shown by the arrow R, the rotational force of the rotor 17 is transmitted to the swash plate 18 through the side face 42a of the rotor-side protrusion 42, which becomes a power transfer side, and the side face 45a of the swash-plate-side protrusion 45 which abuts against the side face 42a. On the contrary, when the drive shaft 16 rotates in the direction reverse to the direction shown by the arrow R, the rotational force of the rotor 17 is transmitted to the swash plate 18 through the side face 43a of the rotor-side protrusion 43, which becomes a power transfer side, and the side face 46a of the swash-plate-side protrusion 46 which abuts against the side face 43a.

That is, in order to increase flexibility, the compressor of this embodiment is constituted to be suitably applied to a vehicle engine regardless of the rotation direction of the engine. In other words, the compressor is constituted to be applied to the engine regardless of whether the rotation direction of the drive shaft 16 demanded by the user is the direction shown by the arrow R or the direction reverse to that shown by the arrow R. Hence, for example, the

hinge mechanism 19 is constituted so as to form a symmetrical shape in the advancing and trailing sides in the rotation direction over the corresponding top dead center region TDC in the rotation direction of the drive shaft 16.

In the above-mentioned engaging groove 41, a cam portion 47 projects as an axial load receiving portion in the base of respective rotor-side protrusions 42 and 43. In each cam portion 47, a cam face 47a, which tilts toward its back side approaching the axis L of the drive shaft 16, is formed in a rear end face that faces the swash plate 18.

Cylinder faces 45b and 46b, which are convex surfaces, are formed at ends of the above-mentioned swash-plate-side protrusions 45 and 46, respectively. The main axis S of the respective cylindrical faces 45b and 46b is perpendicular to the side faces 45a and 46a. The ends of the respective swash-plate-side protrusions 45 and 46 slidably abut against the cam face 47a of the corresponding cam portion 47 through the cylindrical faces 45b and 46b. Therefore, the axial load that acts on the swash plate 18 because of compression reaction force etc. is received by the cam face 47a of the cam portion 47 through the cylindrical faces 45b and 46b of the swash-plate-side protrusions 45 and 46.

Then, for example, when the above-mentioned compressor increases its own displacement, the swash plate 18 is rotated in the clockwise direction as viewed in FIG. 1 with the main axis S of the cylindrical faces 45b and 46b of the swash-plate-side protrusions 45 and 46 as the center. At the same time, the hinge mechanism 19 guides the increase of the inclination angle of the swash plate 18 by the ends of the swash-plate-side protrusions 45 and 46 being moved in the direction of being separated from the drive shaft 16 on the cam face 47a of the cam portion 47.

On the contrary, when the above-mentioned compressor decrease its own displacement, the swash plate 18 is rotated in the counterclockwise direction of FIG. 1 with the main axis S of the cylindrical faces 45b and 46b as the center. At the same time, the hinge mechanism 19 guides the decrease of the inclination angle of the swash plate 18 by the ends of the swash-plate-side protrusions 45 and 46 being moved in the direction of approach towards the drive shaft 16 on the cam face 47a of the cam portion 47.

The above-mentioned hinge mechanism 19 permits the change of the inclination angle of the swash plate 18 while maintaining power transfer to the swash plate 18 from the rotor 17 by enabling the contact engagement of the side faces 42a and 43a of the rotor-side protrusions 42 and 43, and the side faces 45a and 46a of the swash-plate-side protrusions 45 and 46 two-dimensionally. Therefore, when the rotation direction of the drive shaft 16 is as shown by the arrow R, the pressure slide of the side face 42a of the rotor-side protrusion 42 and the side face 45a of the swash-plate-side protrusion 45, which bear power transfer, follows the change of the inclination angle of the swash plate 18. On the contrary, when the rotation direction of the drive shaft 16 is reverse to the direction shown by the arrow R, the pressure slide of the side face 43a of the rotor-side protrusion 43 and the side face 46a of the swash-plate-side protrusion 46, which bear power transfer, follows the change of the inclination angle of the swash plate 18.

In the above-mentioned hinge mechanism 19, the cam face 47a of the cam portion 47 and the cylindrical faces 45b and 46b of the swash-plate-side protrusions 45 and 46 are subjected to a hardening treatment for increasing the durability in mutual pressure slide. The hardening treatment

is performed, for example, by high frequency hardening. Areas where the hardening treatment is applied in the hinge mechanism 19 are the dotted areas 50 and 51 shown in FIGS. 1 to 3. That is, the hardening treatment is applied to limited parts of the cam face 47a of the cam portion 47 and the cylindrical faces 45b and 46b of the swash-plate-side protrusions 45 and 46 in the hinge mechanism 19.

The cam face 47a of the above-mentioned cam portion 47, side faces 42a and 43a of the rotor-side protrusions 42 and 43, side faces 45a and 46a of the swash-plate-side protrusions 45 and 46, and cylindrical faces 45b and 46b are covered with coating films of a solid lubricant. As the solid lubricant, for example, a fluorocarbon resin such as polytetrafluoroethylene, molybdenum disulfide, etc. is suitable. It is possible to decrease frictional resistance and to make the tilt of the swash plate 18 smooth at the time of the displacement change, by forming coating films on the respective sliding surfaces (cam face 47a, side faces 42a and 43a, side faces 45a and 46a, cylindrical faces 45b and 46b).

The above-mentioned swash plate 18 is made to tilt in a direction different from the direction at the time of displacement change since the protruding portion 44 in the engaging groove 41 is pried upward by an offset action of the axial load resulting from a compression reaction force.

In further detailed explanation, as shown in FIG. 3, supposing that the rotational direction of the above-mentioned drive shaft 16 is the direction shown by the arrow R. In addition, assume that the semicircle portion of the swash plate 18 on the compression stroke side, that is, the semicircle portion on the left-hand side of FIG. 3 whose border is an imaginary plane H including the corresponding top dead center region TDC and the axis L of the drive shaft

16 receives a reaction force, pushing the swash plate 18 forward from the piston 23, because of the compression of a refrigerant gas. In addition, the semicircle portion of the swash plate 18 on the charging stroke side, that is, the semicircle portion in the right-hand side of FIG. 3 whose border is the plane H receives a reaction force, pulling the swash plate 18 back from the piston 23, because of the inhalation of the refrigerant gas.

Therefore, the above-mentioned swash plate 18 is tilted in the clockwise direction of FIG. 3, that is, a direction different from the direction at the time of displacement change since the side faces 45a and 46a of the swash-plate-side protrusions 45 and 46 are tilted against the side faces 42a and 43a of the rotor-side protrusions 42 and 43 which face the side faces 45a and 46a.

As mentioned in "Background of the Invention", in order to control the tilt of the above-mentioned swash plate 18 in the direction different from the direction at the time of displacement change, in other words, the prying of the protruding portion 44 in the engaging groove 41, it is necessary to make the play of the protruding portion 44 between the two rotor-side protrusions 42 and 43 small. The play of this protruding portion 44 is determined by a clearance which is a value obtained by subtracting a distance Y between mutually parallel side faces 45a and 46a (refer to FIG. 3) of two swash-plate-side protrusions 45 and 46, which constitutes the protruding portion 44, from a distance X between mutually parallel side faces 42a and 43a (refer to FIG. 2) of two rotor-side protrusions 42 and 43.

In this embodiment, the above-mentioned clearance (X-Y) is set in an optimum range of 0.01 to 0.20 mm, or more preferably, in a rage of 0.03 to 0.11 mm. Namely, if the

clearance (X-Y) is too small, the operation of the hinge mechanism 19 easily reaches a difficult status under the influence of dimensional tolerances, thermal expansion of the rotor 17 and swash plate 18, etc. In addition, when the clearance (X-Y) is too large, there arises a problem in that the protruding portion 44 pries within the engaging groove 41. Therefore, it can be said that the setting range of the clearance (X-Y) mentioned above is a suitable dimensional range for the compatibility of the prevention of prying of the protruding portion 44 in the engaging groove 41 and the prevention of a malfunction of the hinge mechanism 19 resulting from an excessively small clearance (X-Y).

Chamfer processing is given to salient portions 45c and 46c formed by joints of the side faces 45a and 46a and cylindrical faces 45b and 46b in the ends of the above-mentioned swash-plate-side protrusions 45 and 46. The swash plate 18 is produced by casting and the chamfering of the salient portions 45c and 46c of the swash-plate-side protrusions 45 and 46, which is so-called material chamfering concurrently performed at the time of casting of the swash plate 18.

As shown in FIGS. 1 and 2, concavities 61 and 62 as thin-walled portions are formed in the side faces 42a and 43a of the respective rotor-side protrusions 42 and 43 inside the above-mentioned engaging groove 41. That is, the side faces 42a and 43a of the respective rotor-side protrusions 42 and 43 comprise regions (sliding surfaces 42a-1 and 43a-1), which enables abutting engagement with the side faces 45a and 46a of the swash-plate-side protrusions 45 and 46, which face, two-dimensionally, and non-sliding surfaces 42a-2 and 43a-2 located inside the concavities 61 and 62. As for the side faces 42a and 43a of the respective rotor-side protrusions 42 and 43, by the concavities 61 and 62 being formed, areas of

the sliding surfaces 42a-1 and 43a-1 become smaller, for example, in comparison with the case where the concavities 61 and 62 are not provided.

The concavities 61 and 62 inside the above-mentioned engaging groove 41 are provided adjacently to the cam portion 47 in the base of the corresponding rotor-side protrusions 42 and 43. The concavities 61 and 62 extend in a groove-like shape along the direction the cam face 47a extends, that is, along a slide locus on the cam face 47a of the ends of the swash-plate-side protrusions 45 and 46 at the time of displacement change. The non-sliding surfaces 42a-2 and 43a-2 inside the concavities 61 and 62 are continued to the cam face 47a of the cam portion 47.

Therefore, joints (reentrant portions 61a and 62a) of the side faces 42a and 43a of the above-mentioned rotor-side protrusions 42 and 43, and the cam face 47a of the cam portion 47 perpendicular to the side faces 42a and 43a (in detail, the sliding surfaces 42a-1 and 43a-1) are located respectively in positions which enter into the concavities 61 and 62. That is, as shown in FIG. 4, the reentrant portions 61a and 62a which are joints of the side faces 42a and 43a of the rotor-side protrusions 42 and 43, and the cam face 47a of the cam portion 47 are relieved from the ends of the swash-plate-side protrusions 45 and 46 by the formation of the concavities 61 and 62 to the side faces 42a and 43a.

The reentrant portions 61a and 62a inside the above-mentioned concavities 61 and 62 are formed in the shape of a concave surface so as to reinforce the rotor-side protrusions 42 and 43, that is, so as to relax the stress concentration to the reentrant portions 61a and 62a.

In this embodiment with the above-mentioned structure,

the following effects and advantages are obtained.

(1) In the side faces 42a and 43a of the respective rotor-side protrusions 42 and 43, sliding surfaces 42a-1 and 43a-1, which slide on the side faces 45a and 46a of the swash-plate-side protrusions 45 and 46, require highly accurate finish-machining so as to set the clearance of the protruding portion 44 between two rotor-side protrusions 42 and 43 with high accuracy.

However, in this embodiment, since the concavities 61 and 62 are formed in the side faces 42a and 43a of the respective rotor-side protrusions 42 and 43, areas of sliding regions (sliding surfaces 42a-1 and 43a-1) on the side faces 45a and 46a of the swash-plate-side protrusions 45 and 46 decrease sharply in comparison with the case where the concavities 61 and 62 are not provided. Therefore, since the finish-machining of the side faces 42a and 43a of the respective rotor-side protrusions 42 and 43 is required only in a narrow range (sliding surfaces 42a-1 and 43a-1); it is possible to decrease the cost of the finish-machining. Therefore, it is possible to decrease the manufacturing cost of the compressor while attaining highly accurate setting of the clearance of the protruding portion 44 between the two rotor-side protrusions 42 and 43.

(2) The joints (reentrant portions 61a and 62a) of the side faces 42a and 43a of the rotor-side protrusions 42 and 43 and the cam face 47a of the cam portion 47 are relieved respectively by the formation of concavities 61 and 62 from the salient portions 45c and 46c in the ends of the swash-plate-side protrusions 45 and 46.

Therefore, even if the side faces 42a and 43a of the rotor-side protrusions 42 and 43 and the side faces 45a and

46a of the swash-plate-side protrusions 45 and 46 approach in the state where the cam face 47a of the above-mentioned rotor 17 and the cylindrical faces 45b and 46b of the swash plate 18 abut, it is possible to prevent the salient portions 45c and 46c of the swash-plate-side protrusions 45 and 46 from running into the reentrant portions 61a and 62a of the concavities 61 and 62 respectively. Therefore, it is possible to prevent the edges of the salient portions 45c and 46c of the swash-plate-side protrusions 45 and 46 from colliding with the reentrant portions 61a and 62a inside the concavities 61 and 62 or the side faces 42a and 43a of the rotor-side protrusions 42 and 43.

Therefore, it is possible to prevent the generation of abnormal noise resulting from the swash plate 18 tilting for displacement change in a state where these edge collisions arise. In addition, there are also advantages such as the prevention of abrasive degradation of the hinge mechanism 19 and smooth tilt for the displacement change of the swash plate 18. Since it is possible to quickly perform the change operation of the displacement of the compressor by the smooth tilt of the swash plate 18, for example, it is possible to quickly increase the displacement from small displacement, and air conditioning sensation is improved.

In addition, since there is no possibility that the salient portions 45c and 46c of the above-mentioned swash-plate-side protrusions 45 and 46 may run into the above-mentioned reentrant portions 61a and 62a, it is possible to lessen the chamfering of the salient portions 45c and 46c as much as possible. Therefore, it is possible to widen the cylindrical faces 45b and 46b of the swash-plate-side protrusions 45 and 46 without widening widths of the swash-plate-side protrusions 45 and 46 (widths in the crosswise direction in FIG. 3). Therefore, it is possible to increase

the load bearing characteristics of the cylindrical faces 45b and 46b without causing an increase in weight of the swash plate 18.

(3) The concavities 61 and 62 each have a groove-like shape extending along with the cam face 47a of the cam portion 47. That is, what value an inclination angle of the swash plate 18 (displacement of the compressor) may be, joints (reentrant portions 61a and 62a) of the side faces 42a and 43a of the rotor-side protrusions 42 and 43 and the cam face 47a of the cam portion 47 are readily disengaged from ends of the swash-plate-side protrusions 45 and 46. Therefore, even if the swash-plate-side protrusions 45 and 46 move relatively while abutting against the cam portion 47 in connection with the tilt of the swash plate 18 at the time of displacement change, it is possible to prevent the running into of the salient portions 45c and 46c of the swash-plate-side protrusions 45 and 46 to the reentrant portions 61a and 62a of the concavities 61 and 62.

(4) In the side faces 42a and 43a of the rotor-side protrusions 42 and 43, since regions located in the base side of the rotor-side protrusions 42 and 43 are close to the cam face 47a of the cam portion 47, the cam face 47a becomes obstructive, and hence, a tool etc. is difficult to insert. However, in this embodiment, the concavities 61 and 62 which each do not need the finish-machining of an internal surface are provided in the regions of the side faces 42a and 43a located in the base side of the rotor-side protrusions 42 and 43. Hence, in comparison with, for example, the case that the concavities 61 and 62 are formed in regions other than the base side of the rotor-side protrusions 42 and 43 in the side faces 42a and 43a, in other words, the case where it is necessary to perform the finish-machining of regions located in the base side of the rotor-side protrusions 42 and 43 in

the side faces 42a and 43a, it is possible to further decrease the cost of finish-machining of the side faces 42a and 43a (sliding surface 42a-1 and 43a-1).

(5) When the rotational direction of the drive shaft 16 is the direction shown by the arrow R, the concavity 61 is provided in the side face 42a of the rotor-side protrusion 42, which becomes the power transfer side. On the contrary, when the rotational direction of the drive shaft 16 is the direction reverse to the direction shown by the arrow R, the concavity 62 is provided in the side face 43a of the rotor-side protrusion 43, which becomes the power transfer side. Either of the side faces 42a and 43a of the rotor-side protrusions 42 and 43, which is the power transfer side, is a face where the transfer torque between the rotor 17 and swash plate 18 acts. Hence, if the prevention of the running into of the salient portions 45c and 46c of the swash-plate-side protrusions 45 and 46 to the reentrant portions 61a and 62a corresponding to the side faces 42a and 43a occurs, the smooth tilt of the swash plate 18 at the time of displacement change is performed effectively while the prevention effect of abnormal noise generation resulting from this "running into" becomes large.

(6) The concavities 61 and 62 are provided in both the rotor-side protrusions 42 and 43 respectively. Therefore, when the rotational direction of the drive shaft 16 is the direction shown by the arrow R, the concavity 62 is provided also in the side face 43a of the rotor-side protrusion 43, which is not the power transfer side. On the contrary, when the rotational direction of the drive shaft 16 is the direction reverse to the direction shown by the arrow R, the concavity 61 is provided also in the side face 42a of the rotor-side protrusion 42, which is not the power transfer side. That is, whether the rotational direction of the drive

shaft 16 is the direction shown by the arrow R or the reverse direction thereof, it is possible to obtain the advantages of the above-described advantage (5).

(7) The hinge mechanism 19 is subjected to a hardening treatment, limited to parts containing locations of abutment of the rotor 17 and swash plate 18 in the hinge mechanism 19. Hence, in comparison with, for example, the case where the hardening treatment is applied to the entire hinge mechanism 19, the generation of strain, cracks, etc. due to the hardening treatment is suppressed in the hinge mechanism 19. Therefore, since a processing amount of the finish-machining for maintaining the dimensional accuracy of the hinge mechanism 19, such as the accuracy of the clearance (X-Y) of the protruding portion 44 between the rotor-side protrusions 42 and 43 decreases. It is possible to aim at cost reduction.

In particular, since high frequency hardening adopted in this embodiment can provide hardening in the deep portion of a member from a surface of the member, suppressing effects from strain, cracks, etc. of the hinge mechanism 19 mentioned above become large. In addition, since it is possible to reduce, for example, the output of an oscillator which is a facility for high frequency hardening by the hardening treatment being given only to a limited part of the hinge mechanism 19, a hardening treatment with a low-cost facility is possible.

A second embodiment is shown in FIG. 5. In the above-mentioned first embodiment, the thin-walled portions (concavities 61 and 62) are provided in the side faces 42a and 43a of the rotor-side protrusion 42 and 43 respectively. However, in this embodiment, while the thin-walled portions (concavities 61 and 62) are deleted from the side faces 42a and 43a of the rotor-side protrusions 42 and 43, thin-walled

portions are provided in the side faces 45a and 46a of the swash-plate-side protrusions 45 and 46.

In addition, in this embodiment, to prevent the salient portions 45c and 46c of the swash-plate-side protrusion 45 and 46 from running into the joints (reentrant portions 61a and 62a) of the side faces 42a and 43a of the above-mentioned rotor-side protrusions 42 and 43 and the cam face 47a of the cam portion 47, the salient portions 45c and 46c (the salient portion 46c is shown in FIG. 3) are chamfered more than those in the above-mentioned first embodiment.

Hereafter, the thin-walled portions provided in the side faces 45a and 46a of the above-mentioned swash-plate-side protrusions 45 and 46 will be explained. In addition, since the thin-walled portion provided in the side face 46a of the swash-plate-side protrusion 46 in another side is the same as that of the thin-walled portion provided in the side face 45a of the swash-plate-side protrusion 45, its explanation will be omitted.

That is, in the side face 45a of the above-mentioned swash-plate-side protrusion 45, a second plane 45a-2 which tilts relative to the first plane 45a-1 is formed connecting to a region (first plane 45a-1), which mainly slides on the side face 42a (the sliding surface 42a-1) of the rotor-side protrusion 42 in a region in the vicinity of the salient portion 45c (end side). The second plane 45a-2 is formed by machining after the casting of the swash plate 18, that is, after the chamfering of the salient portion 45c. In addition, the main axis S of the cylindrical face 45b is perpendicular to a first imaginary plane K1 containing the first plane 45a-1.

The above-described second plane 45a-2 is tilted so as

to separate from the side face 42a of the rotor-side protrusion 42 as the end side of the swash-plate-side protrusion 45 becomes near. A distance Y' between the second plane 45a-2 of the swash-plate-side protrusion 45 and a similar second plane of the swash-plate-side protrusion 46, which is not shown, becomes narrower as end sides of the swash-plate-side protrusions 45 and 46 become near. That is, a distance between the second plane 45a-2 and the side face 42a of the rotor-side protrusion 42, which faces the second plane 45a-2, becomes wider as the end side of the swash-plate-side protrusion 45 becomes near.

The wall thickness of the above-mentioned swash-plate-side protrusion 45 becomes less than that of the swash-plate-side protrusion 45 in the above-mentioned first embodiment, which does not have the second plane 45a-2, by forming the second plane 45a-2. That is, in this embodiment, the second plane 45a-2 forms the thin-walled portion.

Here, a suitable range exists in a reasonable range (> 0° and < 90°), which achieves the tilt, as an inclination angle $\alpha$ of the second plane 45a-2 relative to the above-mentioned first plane 45a-1.

That is, the smaller the inclination angle $\alpha$ of the second plane 45a-2 is to the above-mentioned first plane 45a-1, the larger a positional gap of a joint P of the first plane 45a-1 and second plane 45a-2 in the vertical direction as viewed in the drawing becomes because of processing error of the second plane 45a-2. For example, even if the second plane 45a-2 shifts a little leftward as viewed in the drawing, the joint P shifts greatly downward as viewed in the drawing, and as a consequence, the first plane 45a-1 decreases greatly. For this reason, the amount of contact area of the swash-plate-side protrusion 45 and rotor-side protrusion 42 becomes

small, and hence, the protruding portion 44 is easily pried against the engaging groove 41.

In consideration of the above issues, the inclination angle $\alpha$ of the second plane 45a-2 to the above-mentioned first plane 45a-1 is set as 1° or more, or more preferably, 2° or more in this embodiment.

In addition, if the inclination angle $\alpha$ of the second plane 45a-2 to the above-mentioned first plane 45a-1 is too large, a part of the second plane 45a-2 is directly connected to the cylindrical face 45b without the salient portion 45c intervening. Therefore, burrs are generated in this part, which is directly connected, and hence, a step for removing the burrs is newly needed. In addition, the area of the cylindrical face 45b becomes small, and hence, the load bearing characteristics of the cylindrical face 45b drop. Therefore, in this embodiment, the inclination angle $\alpha$ of the second plane 45a-2 to the first plane 45a-1 is set so that a second imaginary plane K2 containing the second plane 45a-2 may not intersect the cylindrical face 45b.

That is, in this embodiment, as shown by a dotted and dashed line in FIG. 5, when the inclination angle $\alpha$ of the second plane 45a-2 to the above-mentioned first plane 45a-1 is 6° or more, the second imaginary plane K2 is intersected by the cylindrical face 45b. Therefore, in this embodiment, the inclination angle $\alpha$ of the second plane 45a-2 to the first plane 45a-1 is set as less than 6°.

Furthermore, when the above-mentioned inclination angle $\alpha$ is close to 6°, a possibility that the second imaginary plane K2 intersects the cylindrical face 45b becomes large by a positional gap of the joint P, resulting from processing error of the second plane 45a-2, downward as viewed in the

drawing. Therefore, it is more preferable to set the inclination angle α of the second plane 45a-2 to the first plane 45a-1 at 3° or less.

In this embodiment with the above-mentioned structure, similar advantages to the above-mentioned advantages (5) to (7) are obtained. In addition, in the side faces 45a and 46a of the swash-plate-side protrusions 45 and 46, it is possible to omit the finish-machining for maintaining the accuracy of the clearance (X-Y) in regard to a part where the thin-walled portions (the second plane 45a-2 (the second plane of the side face 46a is not shown)). Therefore, it is possible to reduce the finishing work area for maintaining high accuracy of the clearance (X-Y) and to aim at cost reduction.

In addition, the plane (the second plane 45a-2) is adopted as the above-mentioned thin-walled portion. Therefore, even if the swash plate 18 is tilted in a direction different from that at the time of displacement change and the first plane 45a-1 of the side face 45a of the swash-plate-side protrusion 45 is tilted to the side face 42a of the rotor-side protrusion 42, the second plane 45a-2 abuts against and engages with the side face 42a two-dimensionally. Therefore, the tilt of the swash plate 18 on the displacement change becomes smooth, and hence, it is possible to maintain good displacement controllability.

As shown in FIGS. 6 and 7, in a third embodiment, aligning means 79 for aligning the swash plate 18 with the axis L of the drive shaft 16 is provided.

That is, on the above-mentioned drive shaft 16, a ring member 80 as an aligning member is provided slidably along the axis L. The ring member 80 intervenes between a spring 36 and the swash plate 18. The ring member 80 is pushed on the

swash plate 18 by the spring 36. A ring-side guide portion 82 which has an inclination angle of 45° and consists of a taper is formed in an angle portion in the side of the swash plate 18 in the outer peripheral side of the ring member 80.

In the insertion hole 20 of the above-mentioned swash plate 18, a swash-plate-side guide portion 83 consisting of a taper is formed in back and near parts, as viewed in FIG. 6, around an opening in the side of the rotor 17 (the swash-plate-side guide portion 83 of the back part as viewed in FIG. 6 is shown in FIG. 7). The swash-plate-side guide portion 83 is made in such a shape that, in each value of the inclination angle of the swash plate 18 which changes according to the tilt of the swash plate 18, a part that faces the ring-side guide portion 82 may have an inclination angle of 45° to the vertical direction in FIG. 7. The spring 36, ring member 80 (ring-side guide portion 82), and the swash-plate-side guide portion 83 constitute the aligning means 79.

The above-mentioned ring-side guide portion 82 is pushed slidably on the swash-plate-side guide portion 83 due to thrust of the spring 36 at an arbitrary value of the inclination angle of the swash plate 18. The alignment (alignment in the vertical direction of FIG. 7) of the swash plate 18 with the axis L is performed by this push. Hence, it is possible to prevent prying of the rotor-side protrusions 42 and 43 and the swash-plate-side protrusions 45 and 46, which is caused by misalignment of the swash plate 18 with the axis L.

As shown in FIGS. 8 and 9, in a fourth embodiment, a protruding portion is provided in the rotor 17, and a wall portion is provided in the swash plate 18, respectively.

That is, an engaging groove 70 is formed in the corresponding top dead center region (spherical surface central point of the shoe 25 corresponding to the piston 23 in the top dead center position) side of the swash plate 18 in the front face of the above-mentioned swash plate 18. The engaging groove 70 is formed by two wall portions 71 and 72 provided in the advancing and trailing position of the rotational direction in the front face of the swash plate 18 in a protruding manner toward the rotor 17.

In the above-mentioned rotor 17, a protruding portion 73 is provided in a position corresponding to the engaging groove 70. The protruding portion 73 transmits power to a side face 71a of the wall portion 71 in the swash plate 18 with a side face 73a in the state of being inserted and engaged between the side faces (wall surfaces) 71a and 72a of the wall portions 71 and 72, which face each other (when the rotational direction of the drive shaft 16 is the direction shown by the arrow R). When the rotation direction of the drive shaft 16 is reverse to that shown by the arrow R, the protruding portion 73 transmits power to the side face 72a of the wall portion 72 in the swash plate 18 with a side face 73b.

A cam portion 74 as an axial load receiving portion is formed in the sides of both side faces 73a and 73b of a base of the above-mentioned protruding portion 73. The convex surface-like cylindrical faces 71b and 72b formed in the ends of the wall portions 71 and 72 are slidably abutted against a cam face 74a formed in the rear edge face of the cam portion 74. Furthermore, in both side faces 73a and 73b of the protruding portion 73, concavities 75 and 76 as thin-walled portions are provided in positions near to the ends of the wall portions 71 and 72.

The above-mentioned concavities 75 and 76 are provided on the side faces 73a and 73b adjacently to the cam portion 74, and each have the shape of a groove extending along the relative movement direction to the cam face 74a of the cylindrical faces 71b and 72b of the wall portions 71 and 72 in connection with tilt of the swash plate 18 on the displacement change. Reentrant portions 75a and 76a in the side of the cam face 74a in the concavities 75 and 76 are formed respectively in concave-curved shapes for the reinforcement of the protruding portion 73.

In this embodiment, it is possible to reduce the area of finish-machining for maintaining high accuracy of a clearance in regard to the clearance of the protruding portion 73 between the two wall portions 71 and 72 similarly to the advantage (1) of the above-mentioned first embodiment. In addition, it is possible to prevent the ends of the wall portions 71 and 72 from running into the reentrant portions 75a and 76a similarly to the advantages (2) and (3) of the above-mentioned first embodiment. Furthermore, in this embodiment, the same advantages as the above-mentioned advantages (4) to (7) are obtained.

In addition, it is possible to practice the present invention, for example, in the following aspects within the scope and spirit of the present invention.

A modified example of the above-mentioned first embodiment, as shown by the double-dashed, chain line M in FIG. 4, is to provide chamfering of the salient portion 42b, located in the end side of the rotor-side protrusion 42, among salient portions which are joints of the sliding surface 42a-1 and the non-sliding surface 42a-2 inside the concavity 61 in the side face 42a of the rotor-side protrusion 42. In addition, this chamfering may also be

provided on the salient portion 43b (refer to FIG. 2) which is a junction of the sliding surface 43a-1 and the non-sliding surface 43a-2 inside the concavity 62 in the side face 43a of the rotor-side protrusion 43.

In this way, for example, by the swash-plate-side protrusion 45 tilting, when the side face 45a of the swash-plate-side protrusion 45 separates from the side face 42a of the rotor-side protrusion 42, and the side face 45a of the swash-plate-side protrusion 45 abuts against the salient portion 42b of the rotor-side protrusion 42, the pressure with which the salient portion 42b receives from the side face 45a of the swash-plate-side protrusion 45 is easily distributed in the rotor-side protrusion 42. Therefore, it is possible to increase the load bearing characteristics of the rotor-side protrusion 42.

A modified example of the above-mentioned fourth embodiment, as shown by the double-dashed, chain line M in FIG. 8, is to provide chamfering for the salient portions 73c and 73d in the end side of the protruding portion 73 among salient portions which are joints of the sliding surfaces 73a-1 and 73b-1, which are abutted and engaged two-dimensionally with the wall surfaces 71a and 72a of the wall portions 71 and 72, and the non-sliding surfaces 73a-2 and 73b-2 inside the concavities 75 and 76 in the side faces 73a and 73b of the protruding portion 73.

In this case also, since pressure is easily distributed in the protruding portion 73 even if the salient portions 73c and 73d are provided with the pressure from the side faces 71a and 72a of the wall portions 71 and 72, it is possible to increase the load bearing characteristics of the protruding portion 73.

In the above-mentioned first embodiment, the concavities 61 and 62 may also be provided in locations other than those near to the ends of the swash-plate-side protrusions 45 and 46 in the side faces 42a and 43a of the rotor-side protrusions 42 and 43.

In the above-mentioned first to third embodiments, it is sufficient that the thin-walled portion is provided in at least one of four faces consisting of both side faces 42a and 43a of both rotor-side protrusions 42 and 43, and both side faces 45a and 46a of both swash-plate-side protrusions 45 and 46.

In the above-mentioned respective embodiments, as long as hardening treatment of the hinge mechanism 19 is applied to a part of the hinge mechanism 19 containing at least a part of an abutting location of the rotor 17 and swash plate 18 instead of the entire hinge mechanism 19, hardening treatment may be applied to any part. For example, hardening treatment may also be applied to the end sides of the rotor-side protrusions 42 and 43 (lower part of FIG. 2) and abutting locations with the rotor-side protrusions 42 and 43 in the base of the swash-plate-side protrusions 45 and 46 in the first to third embodiments. In addition, the hinge mechanism 19 may also have such structure that a hardening treatment is applied only to respective single sides of the rotor 17 and swash plate 18 in the state that at least a part of abutting locations of the rotor 17 and swash plate 18 is included.

Although the thin-walled portions are provided only in the wall portions (rotor-side protrusions 42 and 43) of the rotor 17 in the above-mentioned first embodiment and the thin-walled portion is provided only in the protruding portion 44 of the swash plate 18 in the above-described

second embodiment, this may also be changed such that thin-walled portions are provided in both the wall portions (rotor-side protrusions 42 and 43) and protruding portion 44.

In the above-mentioned second embodiment, a thin-walled portion consisting of concavities similar to the concavities 61 and 62 in the first embodiment may also be provided additionally in the base of the swash-plate-side protrusions 45 and 46.

The present invention may be embodied in a wobble type variable displacement compressor provided with a wobble plate as a cam plate.

The present invention may be embodied in a double-headed piston type variable displacement compressor.